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Digital Recording and Analysing of Flight Test Data:

A Proposed System

By

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Digital Recording and Analysing of Flight Test Data - a Proposed System

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SUMMARY

A small digital recorder is proposed, to punch 10,000 instrument readings on 100 ft of cine film, each item to 3 decimal or 12 binary places. Any number of instruments could be recorded, at 10 readings a second. A further unit is envisaged, to read the punched data; to correct each item for instrument errors; to display the corrected values; and to punch them on Hollerith cards or RAESCC tape.

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1 Introduction

At the Aircraft and Armament Experimental Establishment, flight tests are to be recorded in the air, for later analysis. Each instrument reading will be digitally encoded and recorded at intervals, on tape. Analysis may involve four stages. Each reading may need recoding, for easy manipulation, and also correcting, for instrument errors; the corrected values will be scrutinised and then may be fed to an automatic calculator, such as RAESCC (Ref.1) or Hollerith equipment. This note describes means for recording, recoding and correcting such digital data, and indicates how the corrected values may be typed and/or punched, on Hollerith cards or on tape legible by RAESCC. The problem is considered in general terms, as it is unlikely that AAEE will be the only users of such equipment. The project is now being handled jointly by Instrumentation and Mathematical Services Depts., R.A.E.

The necessary digital encoding is not detailed, it being assumed that each instrument reading is represented by the presence of a potential on one or more of N wires serving the recorder. AAEE proposed that this feed be arranged by attaching to each instrument a ratchet-driven follow-up servo, feeding potentials to the recorder via commutators, according to a pure binary code (Ref.2). By this means, any number of instruments can be recorded at once, by halting the follow-up slaves; recording their coded readings; and then allowing each slave to re-align itself with its master.

AAEE require each reading to 1 part in 1000. This demands 10 binary digits, or 12 channels on a binary-coded decimal system, in which each of 3 decimal digits of a reading is coded separately by 4 binary digits. For simplicity the pure binary system is preferred, but it is proposed to provide 12 recording channels, so that either code can be used.

2 The Recorder

2.1 Layout of readings on tape

To simplify the tape drive, one width of tape must suit all applications of the recorder. There are only three simple choices. Each transverse line on the tape can record all readings taken at any instant, one reading, or a single digit. Of these schemes the first, using wide tape, though fast is undesirable, because the number of instruments in each application is unknown. If generous provision is made, space and weight are wasted whenever the number of instruments falls below the maximum - and both space and weight are at a premium in research aircraft; while if the maximum is cut too fine, sooner or later users will call either for more recorders or for extra capacity in each unit. The third scheme, in which each digit occupies a line, would restrict neither the number of instruments which could be recorded nor the accuracy of each reading, but it would be slow and would waste much tape on margins - and on sprocket holes if needed by the drive.

A useful flexible compromise is provided by the second scheme, in which each instrument reading occupies one line across the tape, and readings of successive instruments appear on a group of transverse lines. The accuracy of each reading is then restricted, but the number of instruments is limited only by the time available for recording and re-alignment of slaves, between successive groups of readings. It is this scheme which is adopted in the recorder. Values of more than 3 decimal digits can be considered in two or more parts, as separate readings on successive transverse lines.

2.2 Tape form

The only feasible recording media are magnetic tape or wire, photo film, teledeltos paper, or punched tape. Magnetic tape or wire and photo film are unsuitable, because their performance cannot be checked easily while airborne. Teledeltos paper is flimsy and tends to clog the necessary pens; moreover, automatic reading of its records would be unreliable, due to poor contrast between the marks and base and also to spurious marks caused by rough handling.

Punched tape is therefore the safest choice. It needs little control in the air, the record is visible and easily read photoelectrically, and the tape can be robust enough to withstand constant handling. Photoelectric reading demands an opaque tape, for which the readily available material is blue leader film, used to exclude light from spools of sensitised film. Its fire hazard - no greater than for ordinary film - could be eliminated by substituting the parchmentised paper used in the RAF multi-printer, but it might be necessary to blacken this material and also slit it to optimum width, whereas blue leader is already available in a suitable size.

The 13 holes demanded in para.2 can be punched - slightly staggered - between the sprocket holes of 35 mm blue leader film, at ten readings per inch and per second. A 100 ft spool thus provides about 40 minutes recording of 10 instruments at 2 second intervals; it would require a recorder of overall size about 8 x 6 x $2\frac{1}{2}$ inches. The design could allow units to be stacked, so that capacity could be increased without mechanical modification, and each unit could contain a selector for sampling the instruments to be recorded (see Fig.1).

2.3 Sampling of instrument readings

So far it has been assumed that all the slaves are halted till the last of their readings has been punched on the record tape. With a little extra equipment in each slave, it would be possible to overlap the punching and re-alignment periods, so possibly doubling the maximum recording rate, and the same equipment would enable the recorder to deal with any number of instruments, without modification.

The recorder and slaves would then be arranged electrically in a ring, each joined to its neighbour by a multi-core cable. When the recorder received an initiator pulse from an external timing device, it would halt all the slaves and start sampling the reading of one of its neighbours. Immediately that reading had been punched, the slave would pass on the sampling power to its neighbour, and start to re-align with its master while the reading of the second slave was recorded. This sequence would repeat round the ring, till the last slave passed the sampling power back to the recorder and switched it off, till the next timing pulse. Any number of slaves could form the ring, and if the instruments they followed were arranged in descending order of rate of change, the re-alignment period allocated over and above the punching period would be negligible.

3 The Analyser

3.1 General arrangement

Once the readings have been punched on film, the task must be faced of reading each item, recoding it if necessary, correcting it for instrument error, displaying the corrected value, and possibly punching it on cards or tape. A scheme for accomplishing this sequence automatically is shown in Fig.2. It involves further tapes and deals with each recorded instrument in turn.

A conversion tape carries each possible reading, in monotonic order and in the same code as used for recording; it can be prepared easily with a standard recorder and ratchet-driven commutator. A similar calibration tape is needed for each recorded instrument. It effectively defines a unit step function approximating to the instrument correction plotted against scale reading, recording on each line the successive scale values at which the correction step function changes, together with the sign of the relevant increment or decrement.

The analyser provides three drives, one each for the record and conversion tapes and one for a chosen calibration tape. The record drive locates successive readings of any chosen instrument under a photoelectric reading head, the conversion drive shifts the conversion tape till the value read from it agrees with that selected from the record tape, and the calibration tape moves till two adjacent scale values read from it bracket the reading from the record tape. The motions of the conversion and calibration drives are combined by a differential adding gear and a reverse gear, to drive a decimal counter to the corrected value; this can be read off digit by digit to a typewriter or suitable punch, before repositioning the record tape and starting the sequence again.

3.2 Technique

Each reading head employs a flying spot. A photocell under each of the record and conversion tapes forms a train of pulses as a light spot is traversed across each coded value, from its most significant digit. The resulting pulse trains can be compared easily, the first inequality between them being used to drive the conversion tape towards equality. A similar arrangement controls the calibration drive; two photocells read adjacent values from the calibration tape and their pulse trains are compared with that from the record cell.

Both the conversion and calibration tapes have to move either way as fast as possible, to reduce the settling time of the device. But the speed of traverse of the spots can be high enough to allow these motions to be continuous, rather than step-by-step, given an accurate brake to halt the counter at the true reading. By contrast, the record tape can skip forward slowly to successive readings of any chosen instrument, but needs a fast rewind.

3.3 Layout

A provisional layout of the analyser is shown in Fig.3. The device is based on a platen 19 inches wide by $10\frac{1}{2}$ high. From this platen protrude feed and take-up spindles for the record film and three reading heads, each formed round a waisted sprocket. From the left, the heads deal with the record, conversion and calibration tapes, respectively. The first two have a single photocell each, supported round the waist of the sprocket. The calibration head has two main cells arranged to read adjacent values from that tape, and two auxiliary cells reading the signs of the corresponding increments. Above the heads, a mirror system rotates, deflecting light spots - from lamps behind the platen - in synchronism across the three films. The corrected readings appear in turn on the output counter at the top right hand corner, and can be read therefrom through mechanical contacts to a typewriter, or to a card or tape punch. No spools are provided for the conversion or calibration tapes, which will be less than 8 ft long; their ends dangle towards the floor. Should the capacity of the instrument be extended, spools could be fitted below the platen.

The mirror spindle is driven by a motor behind the platen, through a clutch able to transmit one or more complete revolutions. The spindle drives through a reversing clutch to the conversion sprocket and then via an on-off clutch to the calibration sprocket. Motion of the conversion sprocket reaches the output counter through a differential, and motion of the calibration drive is added to or subtracted from that counter according to the sign of the increments passing the calibration head, through another reversing clutch and the differential.

The record sprocket is driven through a one revolution clutch and an adjustable reduction gear, and is so able to locate successive readings of any chosen instrument.

3.4 Loading

Correct loading of the analyser is essential. With the output counter at zero, each of the conversion and calibration tapes must be loaded with its first reading at a datum. For the record tape, the adjustable gear box is first set to the number of instruments recorded, and then the first of the instrument readings to be corrected is located at the top of the record sprocket. In each forward run of the record tape only one instrument can be dealt with, and the initial position of the record tape must therefore correspond with the calibration tape loaded.

3.5 Action

When the device is switched on, power reaches the motor and a slugged relay, which closes after the motor has accelerated and operates the clutch to the mirror spindle. It thus initiates comparison of the reading chosen from the record tape with the first readings on the other tapes. In general, both comparisons will reveal inequalities. At the end of the first revolution of the mirror, therefore, three drives are clutched in. One connects the mirror spindle and the conversion sprocket; another the conversion and calibration sprockets; and the third invokes either the forward or the reverse clutch between the calibration sprocket and the differential, according to the sign of the first increment on the calibration tape. During the second cycle of the mirror, therefore, the conversion and calibration tapes are both moved on by one reading and towards the end of this cycle the light spots compare the new readings with that from the record tape.

In general it will take more than one cycle to equalise the readings from the conversion and calibration tapes with that from the record tape. The first two drives listed above remain engaged for several cycles, with the third drive controlled by the signs of increments passing the calibration reader. The calibration tape will usually reach equality before the conversion tape, and should never lag behind it.

When equality is sensed between the calibration and record tapes, towards the end of some cycle of the mirror, relays in the circuits comparing the pulse trains from the relevant photectors disengage the clutch between the conversion and calibration sprockets, and lock both the calibration sprocket and the incremental input to the differential. In some subsequent cycle, the conversion and record tapes reach equality and similar relays disengage the conversion drive, to lock both it and the output counter - the latter holding the corrected instrument reading.

Drive is then switched from the mirror to the record tape, to move the latter forward to the next reading of the chosen instrument, and to transfer the three digits on the output counter in turn to the typewriter or tape/card punch. When this action is complete, drive is switched back to the mirror and the cycle repeats, for another reading.

There may be a delay of up to 100 seconds before the first corrected reading is available on the output counter. But thereafter the conversion tape will only have to move a distance determined by the difference between successive readings of the chosen instrument - a difference which will usually be quite small, and which can be dealt with quickly at 10 steps per second.

Two methods are available for stopping the process when sufficient data have been read and corrected. A counter could be attached to the record drive, to halt the device and ring a bell after extraction of a preset number of readings, or alternatively some form of mark on the record tape could serve the same purpose, as it passed the reading head.

3.6 Development

The present scheme involves manual resetting after treatment of each instrument. It might be justifiable to combine the relevant calibration tapes into one and to arrange that after the first instrument in a batch had been treated the record tape was rewound, repositioned for the next instrument, and compared with a second calibration. The whole process of reading a batch of instruments could thus be made automatic.

4 Acknowledgement

It is desired to acknowledge various suggestions made by K.V. Diprose of Maths. Services Dept. and by W. Goldsmith and B.S. Crawshaw of Instrumentation Dept.

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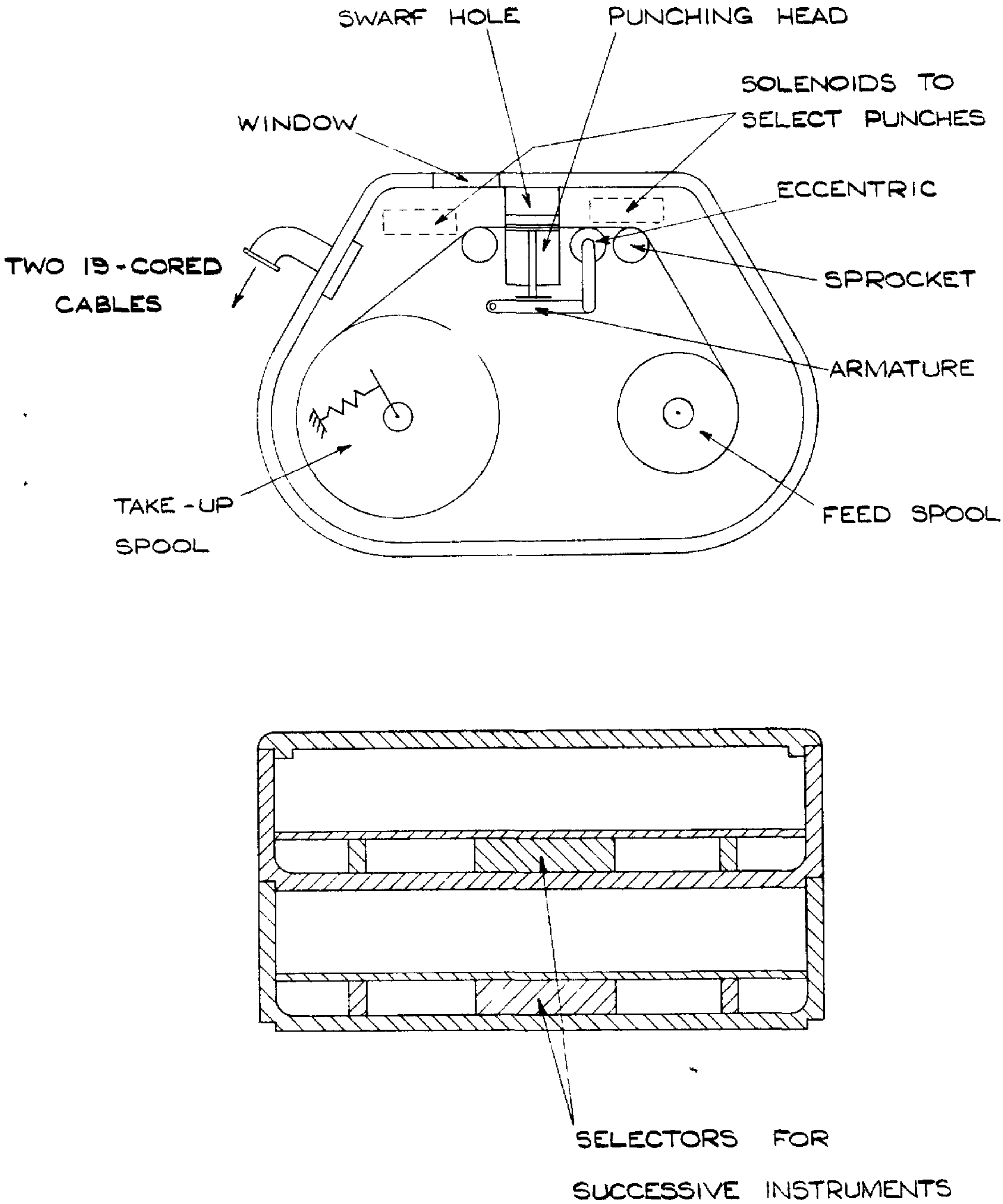

FIG. 1. G.A. RECORDER

FIG 2

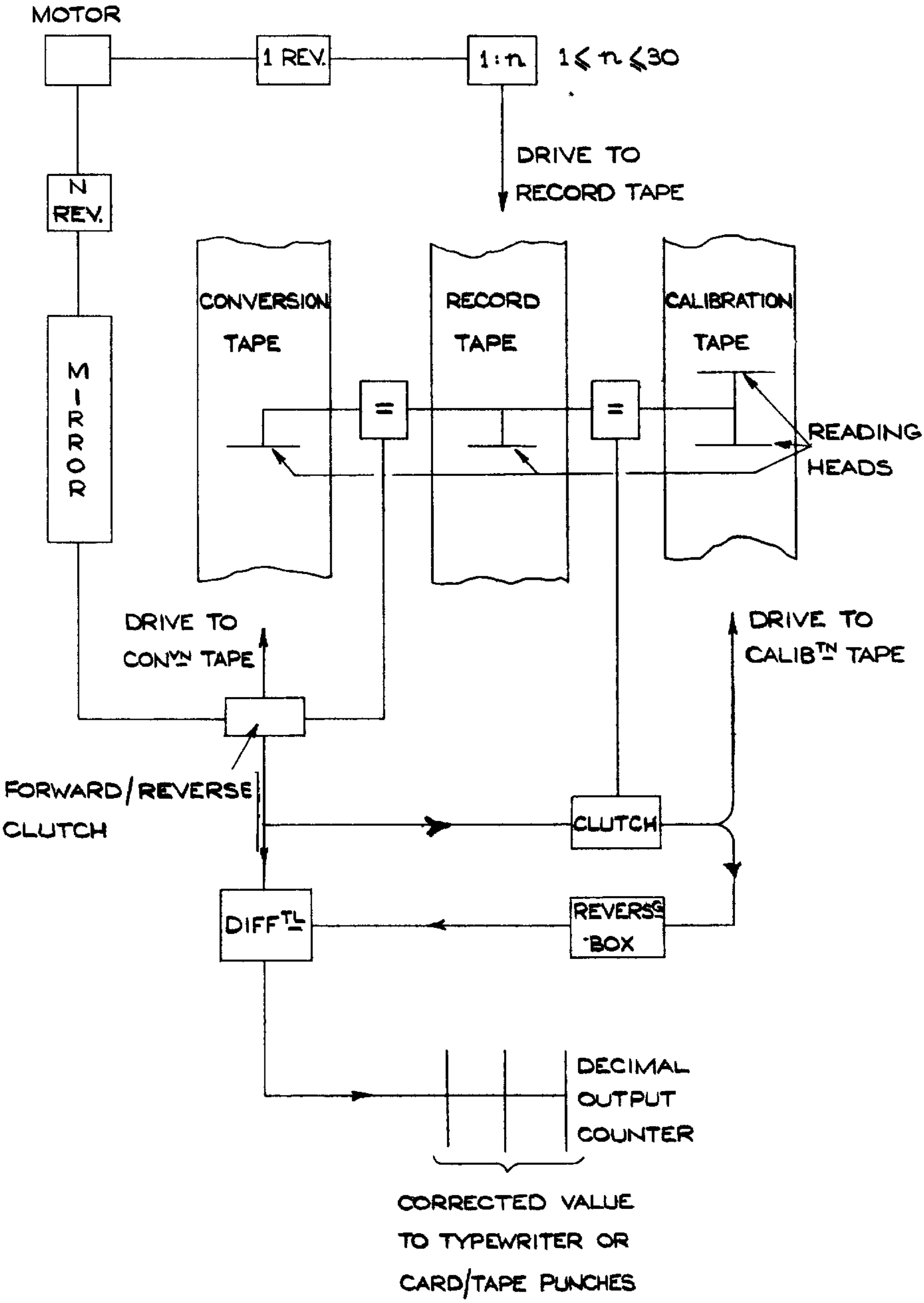

FIG. 2. ANALYSER (SCHEMATIC)

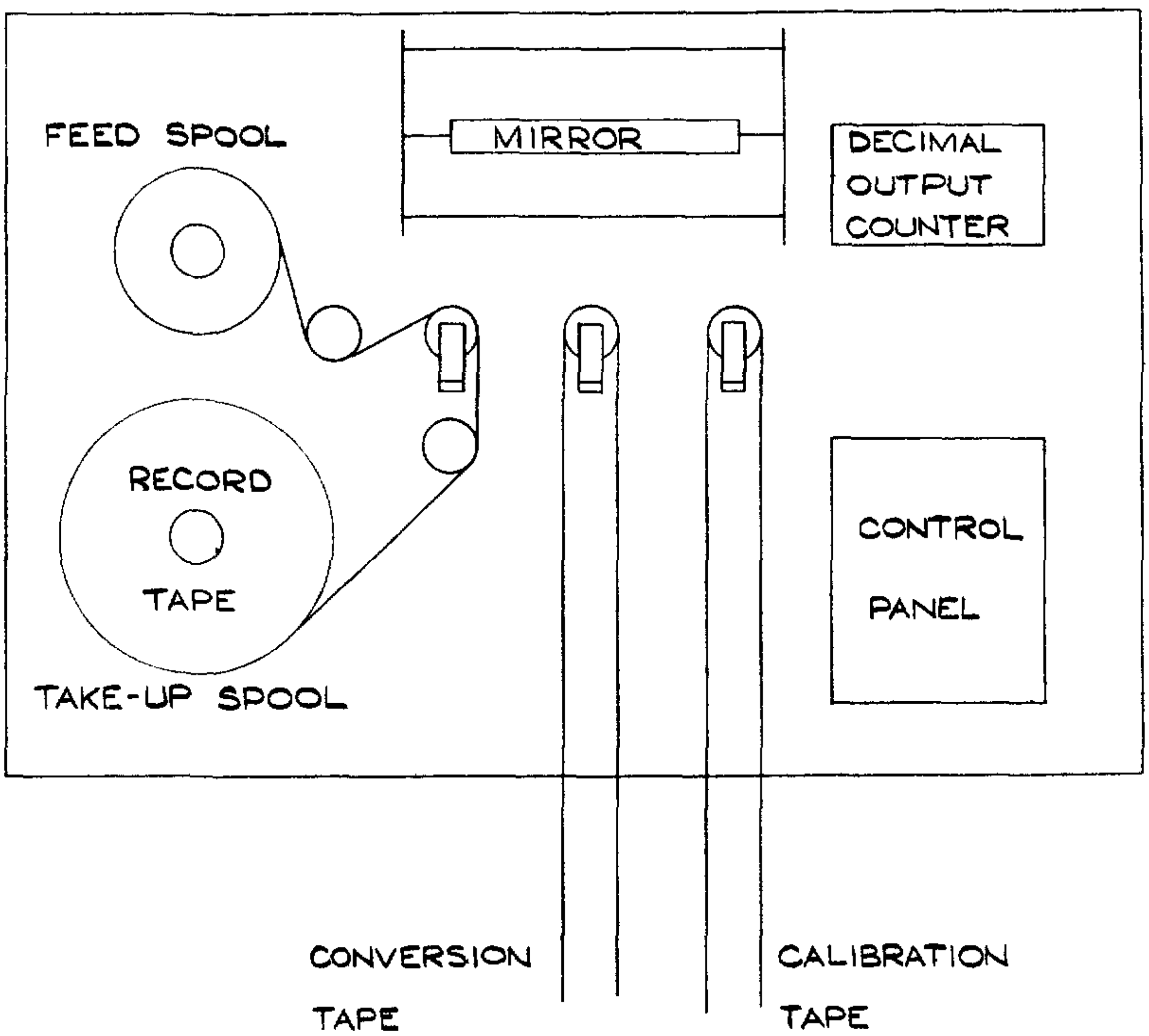

FIG. 3 FRONT ELEVATION OF ANALYSER

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